MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2018/2019 SESSION

PTH 0016 – MODERN PHYSICS AND THERMODYNAMICS

(All sections / Groups)

29 MAY 2019
9.00 a.m. – 11.00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 5 pages with 4 questions and an appendix.
2. Answer **ALL** questions.
3. Write your answers in the Answer Booklet provided.

Question 1

a) A wire of length of 4.35 m and mass 137 g is under a tension of 125 N. A standing wave has formed which has seven nodes including the endpoints.
   i) What is the frequency of this wave? [3 marks]
   ii) What is the fundamental frequency? [1 mark]
   iii) The maximum amplitude at the antinodes is 0.0856 m, write an equation for this standing wave. [4 marks]

b) A violinist is playing his violin while in a car. The note he plays has a frequency of 290 Hz but you hear a note with a frequency of 260 Hz while you are at rest.
   i) Explain ONE (1) evidence that sound is a form of energy. [1 mark]
   ii) Is the violinist moving towards you or away from you? Briefly justify your answer. [2 marks]
   iii) How fast is the car moving? Assume that speed of sound in air is 330 m/s. [4 marks]

Question 2

Light with wavelength $\lambda = 600$ nm is incident on a flat piece of glass with an incident angle of 30°. The index of refraction of glass is 1.52. Calculate:
i) the angle of refraction when the light enters the glass [2 marks]
ii) the speed of the light inside the glass. [3 marks]
iii) the wavelength of the light inside the glass. [3 marks]
iv) the angle of refraction with which the light emerges on the other side of the glass. [2 marks]

Question 3

a) **Figure Q3(a)** shows the typical photoelectric behaviour of a metal as the anode-cathode potential difference ΔV is varied.

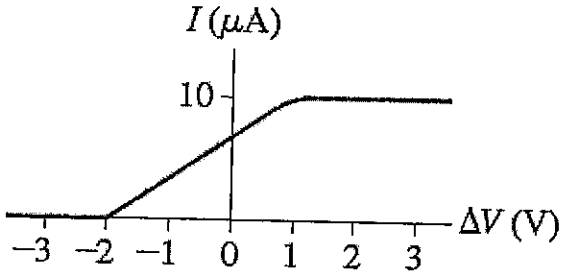

Figure Q3(a)

i) Why do the curves become horizontal for $\Delta V \geq 1V$? Shouldn't the current increase as the potential difference increases? Explain. [1 mark]

ii) Why doesn't the current immediately drop to zero for $\Delta V < 0V$? Shouldn't $\Delta V < 0V$ prevent the electrons from reaching the anode? Explain. [1.5 marks]

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iii) What are the maximum electron speed if sodium is illuminated with light of wavelength 300 nm ? Given that the work function of sodium is 2.75 eV and mass of electron is 9.109×10^{-31} kg.

[2.5 marks]

b) i) **Figure Q3(b)** shows how the number of nuclei of one particular isotope varies with time. What is the half-life of the nucleus? [0.5 mark]

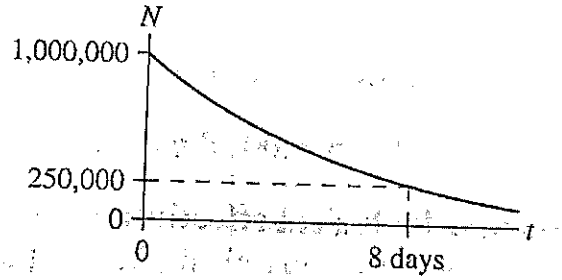

Figure Q3(b)

ii) Nucleus A decays into the stable nucleus B with half-life of 10 s. At $t = 0$ s there are 1000 A nuclei and no B nuclei. At what time will there be 750 B nuclei?

[2 marks]

iii) $^{228}Th \rightarrow {}^{X}Ra + {}^{Y}He$

Find the unknown value of X and Y for the alpha decay of ^{228}Th above. What is the energy (in MeV) released?
Given:
$m(Th) = 228.028715$ u, $m(Ra) = 224.020186$ u, and $m(He) = 4.002602$ u.

[2.5 marks]

Continued...

Question 4

a) 0.50 kg of ice at -10 °C is placed in 3.0 kg of tea at 20 °C. Calculate:

i) the energy needed to raise the temperature of the ice from -10 °C to 0 °C. [3 marks]

ii) the energy needed to change the ice to water at 0 °C. [3 marks]

iii) the final temperature. [3 marks]

iv) State the phase of the mixture when thermal equilibrium is reached. [1 mark]

b) A football player is sitting unclothed in a locker room whose dark wall is at a temperature of 15 °C. Calculate the rate of heat loss by radiation, assuming a skin has temperature of 34 °C, emissivity, $e = 0.70$ and area of 1.5 m^2. [3 marks]

c) An internal combustion engine has a 20 % efficiency and produces an average of 23000 J of mechanical work per second during operation. Calculate:

i) the total heat input per second required. [1 mark]

ii) the amount of heat discharge per second as waste during operation. [1 mark]

Given specific heat capacity of ice = 2100 $Jkg^{-1}°C^{-1}$, specific heat capacity of water = 4186 $Jkg^{-1}°C^{-1}$, specific latent heat capacity of ice = 333000 Jkg^{-1}.

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APPENDIX

LIST OF PHYSICAL CONSTANTS

Electron mass,	m_e	=	9.11×10^{-31} kg
Proton mass,	m_p	=	1.67×10^{-27} kg
Neutron mass,	m_n	=	1.67×10^{-27} kg
Magnitude of the electron charge,	e	=	1.60×10^{-19} C
Universal gravitational constant,	G	=	6.67×10^{-11} N m^2 / kg^2
Universal gas constant,	R	=	8.314 J/mol K
Hydrogen ground state,	E_0	=	13.6 eV
Boltzmann's constant,	k_B	=	1.38×10^{-23} J/K
Compton wavelength,	λ_c	=	2.426×10^{-12} m
Planck's constant,	h	=	6.63×10^{34} J s
		=	4.14×10^{-15} eV s
Speed of light in vacuum,	c	=	3.00×10^8 m/s
Stefan-Boltzmann constant	σ	=	$5.67 \times 10\text{-}8$ Wm^{-2}K^{-4}
Rydberg constant,	R_H	=	1.097×10^7 m^{-1}
Acceleration due to gravity of earth,	g	=	9.80 m/s^2
1unified atomic mass unit,	1 u	=	931.5 MeV/c^2
		=	1.66×10^{-27} kg
1 electron volt,	1 eV	=	1.60×10^{-19} J
Avogadro's number,	N_A	=	6.02×10^{23} mol^{-1}
Threshold of intensity of hearing,	I_0	=	1.0×10^{-12} W/m^2
Coulomb constant,	$k = \frac{1}{4\pi\varepsilon_0}$	=	9.0×10^9 N m^2/C^2
Permittivity of free space,	ε_0	=	8.85×10^{-12} C^2/N m^2
Permeability of free space,	μ_0	=	$4\pi \times 10^{-7}$ T m/A
1 atmosphere pressure,	1 atm	=	1.013×10^5 N/m^2
		=	1.013×10^5 Pa
Wien's displacement constant		=	2.90×10^{-3} mK
Speed of sound in air		=	343 m/s
Refractive index of air/vacuum	n	=	1.0
Earth: Mass,	M_E	=	5.97×10^{24} kg
Radius (mean),	R_E	=	6.38×10^3 km
Moon: Mass,	M_M	=	7.35×10^{22} kg
Radius (mean),	R_M	=	1.74×10^3 km
Sun: Mass,	M_S	=	1.99×10^{30} kg
Radius (mean),	R_S	=	6.96×10^5 km
Earth-Sun distance (mean),		=	149.6×10^6 km
Earth-Moon distance (mean),		=	384×10^3 km

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Formulae

$$\sin\theta_1 + \sin\theta_2 = 2\sin\left(\frac{\theta_1+\theta_2}{2}\right)\cos\left(\frac{\theta_1-\theta_2}{2}\right)$$

$$\cos\theta_1 + \cos\theta_2 = 2\cos\left(\frac{\theta_1+\theta_2}{2}\right)\cos\left(\frac{\theta_1-\theta_2}{2}\right)$$

$$\sin\left(\theta+\frac{\pi}{2}\right) = \cos\theta,\ \omega = k\upsilon = \frac{2\pi\upsilon}{\lambda},\ \omega = 2\pi f,\ Intensity = \frac{Power}{Area},\ \beta = 10\log\left(\frac{I}{I_0}\right)dB$$

$\sin\theta \approx \tan\theta \approx \theta$ *rad* for small angles

$$D(x,t) = D_M \sin(kx \pm \omega t \pm \phi)\ {}_1n_2 = \frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2}$$

$$v = \sqrt{\frac{F_T}{\mu}},\ v = \sqrt{\frac{\text{elastic property of the medium}}{\text{inertia property of the medium}}},\ \mu = \frac{m}{L},\ v = (331+0.60T),\ v = f\lambda$$

$$f_n = \frac{nv}{2L} \qquad f_n = \frac{nv}{4L} \qquad \lambda_n = \frac{2}{n}L \qquad f' = f\left(\frac{v \pm v_o}{v \mp v_s}\right)$$

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f},\ \frac{1}{f} = (n-1)\left\{\frac{1}{R_1} + \frac{1}{R_2}\right\},\ f = \frac{R}{2},\ n_2\sin\theta_2 = n_3\sin\theta_3,$$

$$\sin\theta_c = \frac{n_2}{n_1}\ \text{with}(n_1 > n_2),\ {}_1n_2 = \frac{\sin\theta_1}{\sin\theta_2},\ {}_1n_2 = \frac{1}{{}_2n_1} = \frac{v_1}{v_2},$$

$$d\sin\theta = m\lambda,\ d\sin(\theta) = \left(m+\frac{1}{2}\right)\lambda,\ a\sin(\theta) = n\lambda,$$

$$\lambda_m.T = 0.2898 \times 10^{-2},\ I(\lambda,T) = \frac{2\pi c k_B T}{\lambda^4}$$

$$E_n = -\frac{mk^2e^4}{2\hbar^2}\left(\frac{1}{n^2}\right),\ r_n = \frac{\hbar^2}{mke^2}n^2,\ L = mvr_n = n\hbar$$

$$\frac{1}{\lambda} = R_H\left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right],\ \frac{1}{\lambda} = \frac{mk^2\ Z^2e^4}{4\pi\ c\hbar^3}\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right],\ \lambda = \frac{h}{p}$$

$$R = R_0e^{-\lambda t},\ \lambda = \frac{\ln 2}{T_{1/2}},\ Q = mc^2 = (M_X - M_Y - M_\alpha)\ c^2$$

$$pV = nRT \qquad k = \frac{R}{N_A} \qquad N = N_0e^{-\lambda t}$$

$$\frac{\Delta Q}{\Delta t} = -kA\frac{\Delta T}{\Delta L} \qquad \frac{\Delta Q}{\Delta t} = e\sigma AT^4 \qquad \frac{\Delta Q}{\Delta t} = IeA\cos(\theta)$$

$$\overline{KE} = \frac{1}{2}m\bar{v}^2 = \frac{3}{2}kT,\ U = \frac{3}{2}nRT,\ Q = \Delta U + W$$

$$W = \int dW = \int_{V_i}^{V_f} PdV,\ W = P\Delta V,\ K_{max} = hf - w_o,\ V_{max} = \sqrt{\frac{2K_{max}}{m_e}}$$

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